INTERNATIONAL STANDARD 2277

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Static invertors for aircraft

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FOREWORD

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Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2277 was drawn up by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, and circulated to the Member Bodies in July 1971.

It has been approved by the Member Bodies of the following countries :

Austria	India	Spain
Belgium	Japan	Thailand
Canada	Netherlands	Turkey
Czechoslovakia	New Zealand	United Kingdom
Egypt, Arab Rep. of	Poland	U.S.S.R.
France	Romania	
Germany	South Africa, Rep. of	

The Member Body of the following country expressed disapproval of the document on technical grounds :

U.S.A.

Printed in Switzerland

Static invertors for aircraft

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the general design and test requirements for 400 Hz static invertors for aircraft.

2 REFERENCES

ISO/R 224, *Standard form of declaration of performance of aircraft electrical equipment.*

ISO 1540, *Characteristics of aircraft electrical power systems.*[1)]

3 TERMINOLOGY

static invertor : A unit in which semi-conductor devices are used for deriving alternating current at constant voltage and frequency from a direct current supply.

4 DESIGN REQUIREMENTS

4.1 Unless otherwise required by the individual specification, the design and construction of the invertor shall be such that it is suitable for continuous operation at altitudes up to 18 300 m (60 000 ft). (See section 23.)

4.2 There shall preferably be no limitation in the performance of the invertor in respect of the attitude and location in which it may be mounted.

4.3 All invertors bearing the same identifying number shall be directly and completely interchangeable with respect to installation and performance.

4.4 The design and construction of the invertor shall be such that it is suitable for a minimum of 3 000 h operation between overhauls.

4.5 The invertor shall conform in outline and size to the requirements of the individual specification.

4.6 Unless otherwise specified, the invertor shall be designated to operate from a fully-insulated system, i.e. all the electrical circuits shall be insulated from the frame, and the neutral point shall be brought out to a termination.

5 PREFERRED RATINGS

5.1 The preferred ratings for the invertors at sea level and at a temperature of + 70 °C are as follows :

Rating in VA	
Single-phase	**Three-phase**
100	100
150	250
250	500
500	750
750	1 000
1 000	1 500
	3 000

5.2 If required by the individual specification, the ratings at temperatures of + 55 °C and + 85 °C shall be declared.

6 SUPPLY CHARACTERISTICS

6.1 The invertor shall be capable of operating over the normal input terminal voltage range specified for Category B equipment, excluding emergency conditions, in ISO 1540.

6.2 The invertor shall be capable of withstanding and operating under the conditions of transient and over voltage input indicated by the appropriate curves in ISO 1540.

6.3 The invertor shall be capable of operating with a supply at its terminations having a maximum impedance made up of 50 MΩ resistive and 10 μH inductive components. The ripple voltage superimposed on a smooth d.c. supply of this source impedance shall not exceed 2 V peak-to-peak under steady state conditions.

1) At present at the stage of draft.

6.4 The manufacturer shall declare if the invertor can operate only on a supply capable of accepting reverse current.

7 OUTPUT VOLTAGE AND FREQUENCY

7.1 Single-phase invertors shall have a nominal output voltage of 115 V r.m.s.

7.2 Three-phase invertors shall have a nominal output voltage of 200 V r.m.s. line to line.

7.3 Unless otherwise stated, the requirements of this International Standard for three-phase systems are related to line to neutral voltages.

7.4 The nominal output frequency shall be 400 Hz.

8 EFFICIENCY

8.1 The manufacturer shall declare the maximum value of mean and r.m.s. input current of the invertor at full load, and with the most unfavourable input voltage (see 25.7).

8.2 The efficiency of the invertor on full load, at unity power factor (under the combination of ambient temperature and input voltage specified in the individual specification), shall be not less than 65 %.

9 REGULATION RESPONSE AND STABILITY

9.1 When the load is switched from 10 to 85 % and from 85 to 10 % full load there shall be, after the first main deviation of output voltage, not more than one overshoot before the voltage remains within the modulation tolerance of the final steady state value, except that where the invertor response can be shown to be less than 20 ms, two overshoots may be permissible.

9.2 During normal operation (including load switching from 10 to 85 % and from 85 to 10 % of system capacity of the invertor full load rating), voltage surges, when converted to their equivalent step functions, shall lie between the limits 5 and 6 in Figure 5 b) given in ISO 1540.

10 VOLTAGE BALANCE

For a three-phase invertor loaded as indicated in Table 1, Item 1, the maximum difference between individual line to line voltages and between line to neutral voltages shall not exceed 2 % of their nominal values.

11 WAVEFORM OF OUTPUT VOLTAGE

With the invertor energized as specified in section 6 and supplying the loads indicated in Table 2, each state output voltage waveform at constant frequency shall be in accordance with the requirements of ISO 1540.

12 MODULATION OF OUTPUT VOLTAGE

With the invertor energized as specified in section 6, the modulation of the output voltage shall be in accordance with the requirements of ISO 1540.

NOTE – Since pulse loads are likely to result in excessive modulation, individual specifications should state the nature of pulse loads which can be expected.

13 CONTROL OF VOLTAGE AND FREQUENCY

13.1 Voltage

Under any combination of input voltage specified in section 6 and loads specified in Table 1, Item 1, the individual line to neutral voltages shall be within the normal limits specified in section 5 of ISO 1540.

For three-phase invertors, the manufacturer shall declare the departure from this tolerance, if it exceeds 3 % when the load is unbalanced to the extent indicated in Table 1, Item 2.

The displacement between the line to neutral voltages shall be $120 \pm 2^{\circ}$.

13.2 Frequency

Within the defined range of input voltages the frequency shall be within the limits specified in ISO 1540 for a constant frequency a.c. system.

14 ADJUSTMENT OF VOLTAGE

Internal means shall be provided for adjusting the output voltage over a range of ± 2 %. The means of adjustment shall be capable of being positively locked.

15 PHASE SEQUENCE

The invertor shall be designed so that normal phase sequence is ABC and operation in reverse is not possible.

16 PROTECTION

16.1 Voltage and frequency

If required by the individual specification, means shall be provided for automatic shut-down of the invertor if the steady-state output voltage, or the frequency, exceeds the relevant limits stated in ISO 1540.

16.2 Overload conditions

Unless otherwise required by the individual specification, the invertor shall be able, without damage, to deliver 150 %

rated current for 100 s. The power factor and minimum input and output voltages shall be specified in the individual specification.

16.3 Short-circuit capacity

Unless otherwise required by the individual specification, the invertor shall be able, without damage, to deliver not less than 300 % rated current in each case for a line to neutral and/or each line to line short-circuit for 5 s throughout the specified input voltage range.

16.4 Automatic shut-down

Unless otherwise required by the individual specification, means shall be provided for automatic shut-down on overload conditions exceeding the limits stated in 16.2 and 16.3.

16.5 Input voltage protection

The invertor shall not suffer damage as a result of connection to an input supply having a voltage below the specified minimum.

16.6 Reversed input polarity

Suitable means shall preferably be provided for protecting the invertor from the effects of an inadvertant reversal of polarity.

17 ENVIRONMENT

The invertors shall comply with the requirements of the appropriate International Standards (ISO 2650 et seq) for environmental and operating conditions of aircraft equipment.

18 TERMINAL IDENTIFICATION

Except when termination is by plug and socket connector, the following method of terminal identification shall be adopted.

The phases shall be identified by the letters A, B and C in such a way that the voltages in the phases so marked attain their maximum values in the order A, B and C. The neutral point shall be identified by the letter N. The markings L1 and L2 shall be used for single-phase identification, and plus and minus signs for d.c. terminal identification. If a switching facility is installed in the invertor the control terminal shall be marked SW.

19 COMPONENTS

All components shall conform to an approved specification and shall preferably be selected from approved standard ranges.

20 RADIO INTERFERENCE

The invertor shall be designed to minimize the generation of radio interference. The radiated and conducted noise voltages shall be within the limits specified in the relevant part of ISO ... [1], when measured as described therein.

21 MAGNETIC INFLUENCE

The invertor shall be designed so that the external magnetic fields produced are as small as practicable. Measurements of compass safe distance shall be made in accordance with ISO ... ,[1] and shall be declared by the manufacturer.

22 STARTING

22.1 Starting shall be effected by single initiation.

22.2 The invertor shall be capable of starting under all specified conditions. During starting, the output voltage should not exceed the limit given in Figure 6 of ISO 1540, and the steady state conditions should be achieved within 1 s (see 13.1 and 13.2).

23 COOLING

23.1 The invertor shall have adequate cooling facilities so that continuous operation at full load is possible under ground level conditions at the maximum operating ambient temperature. The temperature conditions obtaining at altitude will depend on the particular application, and will be given in the individual specification.

23.2 For self-cooled, including fan-cooled, invertors the manufacturer shall supply curves indicating the limiting ambient air temperatures for various altitudes, when the invertor is supplying full, three-quarter and half load at nominal input voltage.

23.3 For forced-cooled units, curves shall be supplied showing the mass flow and pressure head of cooling air required for various inlet air temperatures at ground level, 9 150 m (30 000 ft) and 18 300 m (60 000 ft) and with the invertor supplying full, three-quarter and half load at nominal input voltage.

24 TESTS

24.1 Except where specific details are listed below, tests shall be in accordance with the practice and requirements of relevant national specifications for aircraft invertors. Evidence shall be available to the purchaser that invertors

1) In preparation.

identical to those supplied as covered by this International Standard have satisfactorily passed type tests conducted in accordance with section 25. In order that a consistent standard of quality be maintained, the manufacturer shall conduct production acceptance tests in accordance with section 26, and quality tests in accordance with section 27.

24.2 Invertors subjected to type tests shall have passed the production acceptance tests, and the results shall be recorded. The number of samples to be used for the type tests, and the order of tests on a particular sample, shall be stated in the individual specification.

24.3 For inspection purposes, the Inspecting Authority shall be provided with complete manufacturing drawings of the invertor before samples are submitted for approval. The manufacturer shall disclose to the Approving Authority any proposal to introduce changes affecting interchangeability and shall obtain the Approving Authority's written approval before applying the change to production. As soon as series production commences, a complete set of drawings shall be sent to the Approving Authority.

25 TYPE TESTS

25.1 General

25.1.1. Unless otherwise stated, all tests shall be carried out at 29 V and at room temperature, i.e. 20 ± 5 °C.

25.1.2 All d.c. voltages are mean values and shall be measured to an accuracy of ± 1 %.

25.1.3 All r.m.s. a.c. output voltages shall be measured to an accuracy of ± 0,5 %.

25.1.4 To ensure reproducibility of the test conditions, the invertor shall, unless otherwise specified, be supplied from a smooth d.c. source. The preferred source consists of a battery floated across a convenient charging source. The capacity of the battery shall be chosen in conjunction with the characteristics of the charging source and the invertor load to ensure that the ripple injected by the charging source does not exceed 200 mV peak-to-peak.

25.1.5 All test voltages are referred to the invertor input and output terminations. For all tests, other than for transient response, the input voltage shall be adjusted to maintain the specified values independent of the voltage drop in the cable. For transient response tests this is impracticable and for these the source impedance of the supply shall be sufficiently low to maintain input voltage within 1 V of the specified value throughout the test.

25.2 Starting test

The invertor shall be tested at an input voltage of 24 V and 29 V for compliance with section 22. The test shall be performed at maximum and minimum declared operating temperatures at no load and at full load unity power factor.

25.3 Voltage and frequency regulation

25.3.1 The invertor shall be tested with all relevant load combinations detailed in Table 1 to determine that the output voltage and frequency remain within the specified limits. The tests shall be made at input voltages of 24 V and 29 V.

Conditions should be established on the basis of the above tests for such further tests as are necessary to determine that the invertor will comply with the specification requirements under the most adverse load combinations at the extreme of the declared temperature range.

25.3.2 The voltage transient response shall be examined when the invertor is switched from 10 to 85 % and from 85 to 10 % balanced full load unity power factor. The tests shall be made at input voltages of 24 V and 29 V and meet the requirements of section 9.

25.4 Wave form

Under the loading conditions specified in Table 2, each line to neutral wave from shall comply with the requirements of section 11.

25.5 Protection

25.5.1 *Operation under transient voltage and input voltage protection*

The tests described in ISO 1540, Annex B, sections B2 and B4, shall be applied to establish that the invertor, when operating at full load unity power factor, will withstand voltage surges and spikes without damage.

The tests shall be repeated with the invertor operating at one quarter load unity power factor.

25.5.2 *Output over-voltage protection*

With the invertor operating with 29 V d.c. input at half full load unity power factor, a simulated failure shall be introduced in the voltage regulation circuits which demands that the invertor delivers an over-voltage. The output voltage shall not exceed limit 1 of Figure 6 in ISO 1540. At least three output over-voltages, including the maximum voltage of which the invertor is capable, should be chosen to ensure that the envelope meets the requirements of the curve in ISO 1540.

25.5.3 *Output frequency protection*

If output frequency protection is required by the individual specification, test conditions shall be agreed to confirm that the under- and over-frequency protection circuits will operate within 1 s after the output frequency falls or rises outside the limits specified in ISO 1540.

25.6 Voltage modulation

With the invertor operating at 29 V d.c. input, the output voltage envelope shall be examined both at no load and at

balanced full load unity power factor. Any modulation present on the output shall comply with the requirements of ISO 1540.

25.7 Efficiency

The efficiency of the invertor shall be measured at full load unity power factor, with the invertor temperature stabilized at supply voltages of 24 V, 26 V and 29 V, and shall not be less than 65 %.

For the purposes of this specification efficiency is defined as :

$$\frac{V_{ac} \times I_{ac}}{V_{dc} \times I_{dc}} \times 100$$

where

V_{dc} is the mean input voltage;

I_{dc} is the mean input current;

Single-phase invertor

V_{ac} is the r.m.s. output voltage;

I_{ac} is the r.m.s. output current.

Three-phase invertor

V_{ac} is the average of the three r.m.s. line to neutral voltages;

I_{ac} is the sum of the three r.m.s. line currents.

25.8 Input current

25.8.1 *Maximum current demand*

The invertor mean input current shall be measured at full load unity power factor at supply voltages of 24 V, 26 V and 29 V, and shall not exceed the declared value.

25.8.2 *Ripple current*

With the invertor operating at full load unity power factor, an impedance equivalent to 50 mΩ in series with a 10 μH inductance shall be connected between the d.c. supply and the input terminals.

The ripple voltage developed across this source impedance shall not exceed 2 V peak-to-peak, and the test shall be repeated at both 29 V and 24 V at the invertor terminals.

The power supply shall be shunted by sufficient capacitors to keep the ripple voltage across it to less than 5 V peak-to-peak.

25.9 Overload capacity

Immediately following a period of operation at maximum rated operating temperature and full rated load, unity power factor, a load consuming 150 % of rated current at 0,75 lagging power factor shall be connected for 100 s. During the overload, the output voltage shall not fall below the minimum permitted by the individual specification. Immediately, after the overload, the invertor shall be undamaged and shall continue to deliver full rated load, and its output voltage and frequency shall be within their normal tolerances.

25.10 Short circuit capacity

With the invertor operating into full load unity power factor, each line to neutral and/or each line to line shall in turn be terminated in a load resistance 1/100 of the value required to load fully that output.

At minimum specified input voltage the invertor shall deliver without damage a minimum r.m.s. current of 300 % of rated full load current for a period of at least 5 s.

This test shall be repeated with the invertor operating initially at no load and also with this fault load applied before the invertor is switched on.

Immediately following these tests, the invertor shall continue to operate normally.

25.11 Insulation resistance[1)]

The insulation resistance of the invertor shall be measured between :

— d.c. inputs and frame with the a.c. outputs connected to frame : test voltage 50 V d.c.;

— a.c. outputs and frame with the d.c. inputs connected to frame : test voltage 200 V d.c.

At maximum operating temperature the insulation resistance shall not be less than 10 MΩ.

25.12 Cooling test

A cooling test shall be made to establish the curves required by section 23.

25.13 Temperature and pressure tests

The invertor shall be tested in accordance with ISO ... .[2)]

The invertor shall be functional during and after this test. During the test, the limits shall be within those specified in 25.2 to 25.12 and on completion of the tests the performance of the invertor shall be within the limits specified in the production acceptance test.

25.14 Tropical exposure

The invertor shall be tested in accordance with ISO ... .[2)] An insulation resistance test shall be made in accordance with 25.11.

1) Insulation and high voltage testing are the subject of work by ISO/TC 20/SC 1.

2) In preparation.

The invertor shall be functional during and after this test. During the tests the limits shall be within those specified in 25.2 to 25.12 when subjected to Figure 5 or 6 of ISO 1540, and the invertor shall comply with the requirements of the production acceptance test at D in Figure 5 or at the completion of Figure 6.

25.15 Leakage tests for hermetically sealed equipment

If a component part of the invertor is hermetically sealed, that part shall be tested in accordance with ISO ... .[1)]

25.16 Waterproofness

If required by the individual specification, the invertor shall be tested in accordance with the requirements of the appropriate grade stated in ISO ... .[1)]

The invertor is not required to be functional during this test. Immediately following this test the invertor shall start and operate within the limits specified in the production acceptance test.

25.17 Vibration tests

The invertor shall be tested in accordance with the requirements of the appropriate class stated in ISO ... .[1)]

When operating, the performance of the invertor shall be within the limits specified in 25.2 to 25.12.

25.18 Acceleration tests

The invertor shall be tested in accordance with the requirements of the appropriate severity grade specified in ISO ... .[1)]

The invertor shall be functional during and after this test. During the test the limits should be within those specified in 25.2 to 25.12 and on completion of the test the performance of the invertor shall be within the limits specified in the production acceptance test.

25.19 Tests for explosion proofness

If required by the individual specification, the invertor shall be subjected to an explosion proofness test appropriate to the category of enclosure in accordance with ISO ... .[1)]

25.20 Radio interference

The invertor shall be tested in accordance with ISO ... .[1)]

25.21 Measurement of compass safe distance

The invertor shall be tested for magnetic influence and the compass safe distance determined in accordance with ISO ... .[1)]

25.22 Salt corrosion tests

If required by the individual specification, the invertor shall be subjected to a salt corrosion test in accordance with ISO ... .[1)]

At the end of the test, the invertor shall be examined for corrosion and deterioration of metal parts, finishes, materials and components, and it shall be given such functioning tests as may be required by the individual specification.

25.23 Dust and sand tests

If required by the individual specification, the invertor shall be subjected to dust and sand tests in accordance with ISO ... .[1)]

At the end of the test, the invertor shall be examined for local accumulations of dust, and if required by the individual specification, a functioning test shall be made.

25.24 Contamination tests

If required by the individual specification, the invertor shall be subjected to contamination tests in accordance with ISO ... .[1)]

At the end of the test, the invertor shall be examined for signs of deterioration such as softening of paints and waxes, and shall be given such functioning tests as are required by the individual specification.

26 PRODUCTION ACCEPTANCE TESTS

26.1 General

All production tests shall be carried out under the conditions, and with the instruments, detailed in 25.1.

26.2 Phase sequence (three-phase invertors only)

The direction of phase rotation shall be determined. It shall follow the sequence A, B, C.

26.3 Voltage (and frequency regulation)

The invertor shall be tested over the specified voltage range at no load, full load unity power factor, and full load 0,75 power factor lagging, to determine that the output voltage (and frequency) remains within the specified limits. (Should the type test show load combinations which are likely to affect the regulation seriously, then these combinations shall be used in preference to those stated above.)

26.4 Transient response

The invertor shall be switched from 10 to 85 % and from 85 to 10 % full load. The output waveform envelope shall be examined to ensure that it satisfies 9.1.

26.5 Waveform

Such tests as are necessary shall be performed to determine that the output voltage waveform meets the requirements of the specification.

1) In preparation.

26.6 Transient voltage and input voltage protection

Such tests as are necessary shall be performed to show that any transient voltage protection and input voltage protection circuits are functioning.

26.7 Output frequency protection

If output frequency protection is required, the test conditions shall be stated in the individual specification.

26.8 Maximum current demand

The invertor mean input current over the voltage range shall be measured at full load, unity power factor, and shall not exceed the declared value.

26.9 Insulation resistance

The insulation of the invertor shall be measured between :

– d.c. inputs and frame with the a.c. outputs connected to frame : test voltage 50 V d.c.;

– a.c. outputs and frame with the d.c. inputs connected to frame : test voltage 200 V d.c.

The insulation resistance shall be not less than 10 MΩ.

26.10 Voltage balance (three-phase invertors only)

The invertor shall be tested for compliance with the requirements of section 10.

26.11 Production endurance test

Before delivery, each invertor shall be tested for not less than 50 h over a minimum of 50 load changes from no load to full load, and a minimum of 50 starts spread over the 50 h. At the conclusion of the test the invertor shall satisfy the requirements of clauses 26.3 and 26.9.

27 PRODUCTION QUALITY TESTS

27.1 Sampling

27.1.1 Samples shall be taken at random from current production and shall have previously passed the production acceptance tests.

27.1.2 Unless otherwise specified, samples for quality tests shall be selected on a basis of one per 100 produced subject to a minimum of one every 6 months.

27.2 Tests

The samples shall be subjected to the following tests :

1) Short circuit capacity. The invertor shall be tested to confirm compliance with the requirements of the short-circuit capacity test (25.10).

2) Waveform analysis. Under the loading conditions specified in Table 2, each line to neutral wave form shall comply with the requirements of ISO 1540, (clause 4.1.4 and Annex A).

3) Climatic. One per 12 months' production or one per 100 units, whichever is the greater.

4) Vibration test. Resonance search only : one per 12 months' production or one per 100 units, whichever is the greater.

5) Repeat production acceptance tests. At the conclusion of the above tests, the production acceptance tests (section 26) shall be repeated.

28 DECLARATIONS

The declarations made by the manufacturer in accordance with ISO/R 224, shall include the following information :

1) rating at + 55 °C and at + 85 °C, if required by the individual specification;

2) maximum input mean current at full load;

3) non-operating no derangement temperature range;

4) output voltage and power at a reduced input voltage when specified in the individual specification.

29 MARKING

The following minimum information shall be indelibly marked on the name-plate, and the modification plate shall provide for ten modification references :

1) manufacturer's name;

2) manufacturer's type (or part) number;

3) serial (or batch) number.

30 WARNING NOTICES

Any warning notices shall be clearly displayed on the invertor.

TABLE 1 – **Voltage balance loads**

Invertor type	Phase	Load	Power factor
1 Single-phase invertors and three-phase invertors with balanced loads		Full 3/4 1/2 1/4	1 1 1 1
		Full 1/2 1/4	0,75 lagging 0,6 lagging 0,6 lagging
		Full 1/2 1/4	0,95 leading 0,95 leading 0,95 leading
2 Three-phase invertors with unbalanced loads	A B C	Full Full 1/4	1 1 1
	A B C	Full Full Full	1 0,95 leading 0,8 lagging